Standard Measurement & Verification Plan
for
Lighting Equipment Retrofit or Replacement Projects

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Contents

BACKGROUND

This document provides a framework for a standard Measurement and Verification (M&V) plan for lighting projects. It was developed to support cost-effective retrofits (partial and complete replacements) of lighting systems and is intended to serve the following purposes:

- Provide a foundation for an M&V plan for a lighting retrofit utilizing a "best practice" approach, which considers engineering accuracy as well as practicality. This document provides a base document that may need to be customized for individual applications.
- Provide guidance to site owners, contractors, and other involved organizations on what is essential for a robust M&V plan for lighting projects. This document provides examples of appropriate elements of an M&V plan, including the calculation of expected energy savings.

The standard M&V plan, as provided, also allows for consistent comparison with other similar lighting projects. Although intended for lighting retrofit applications, M&V plans developed per this framework document may also be used for other non-lighting technology retrofits and new installations.

M&V PLAN SUMMARY

The M&V approach outlined herein contains many specific parameters. The prescribed methodologies were developed with consideration for technical accuracy and appropriate practicality. Note, however, that this draft plan is intended to be used as a basic approach and may need to be customized for each project.

This approach is suitable for lighting fixture retrofits and/or replacements. The approach is also useful for projects that also include changes to control systems for additional energy savings. Capturing control savings typically requires additional monitoring and calculation. This M&V Plan is particularly applicable to projects where the parties involved seek consistent verification of savings among different projects and technologies.

1.1 Instrumentation Requirements

This standard M&V plan specifies the minimum accuracy requirements of the instrumentation to be used for measurements. Table 1 provides instrument specifications appropriate for use in this M&V plan. Specific instrumentation brands or manufacturers identified in the Table are provided as examples only, and do not represent an all-inclusive list. The documentation of any testing should include the actual specifications and measurement accuracies of any equipment used. If the accuracy is significantly less than the values listed in the table, the measurements from equipment may not be suitable as they introduce additional error into the energy calculations.

Table 1 : Example Instrumentation Specifications

Equipment Type	Purpose	Measurement Uncertainty and range	Meter Characteristics	Example Brand Names*
Illuminance meter	Establish functional performance of baseline and new lighting equipment	▪ Uncertainty: ± 3% ▪ Range: ≤ 0. 1 fc (0.01 lux)	▪ Cosine corrected ▪ Spectral response within 10% of the CIE spectral luminous efficiency function	▪ Minolta ▪ Photo Research ▪ Cooke ▪ Extech ▪ Amprobe ▪
Power meter	Establish true RMS power draw of baseline and new lighting equipment	▪ Uncertainty: ± 3%		▪ Fluke 39/41/41B ▪ Extech 4KC20 ▪ AEMC 3910
Light on/off data logger	Measure run time of lighting fixtures	▪ Uncertainty: ±1 minute per week; Light threshold adjustment range: 1 – 100 fc (10 – 1,000 lux)		▪ Onset Computer Hobo Loggers ▪ Dent Instruments SmartLogger ▪ Omega OM-53

*** NOTE: the brand names listed are examples only. Associated products MAY NOT meet all of the requirements in this table. Verification of the individual equipment is required.**

1.2 M&V Activity Summary

The following table summarizes the key elements present in this standard M&V Plan for Lighting Equipment Retrofits. The content is organized into three sections: Baseline M&V Activities, Post-Installation M&V Activities, and Annual/Periodic M&V Activities.

Table 2 : Summary of Key Elements in Standard M&V Plan for Lighting Retrofits

Baseline M&V Activities:

- Obtain fixture counts from documented lighting audit.
- Measure baseline fixture power for lamp + driver/ballast combinations representing a total of 75% of the baseline connected load.
  - This may be accomplished by measuring a minimum of 75% of the circuit load or at least six individual fixtures of each type and then calculating total load from these representative measurements. Failed light sources must be addressed as described in later section.
  - HVAC interactions are assumed to be negligible.
- Measure or document Baseline Operating Hours based on control timers or schedules.
- Calculate baseline energy use based on product of the baseline fixture power consumption, operating hours, and fixture quantities for each line item in the lighting audit OR product of total circuit load and operating hours.
- Calculate baseline demand based on product of the baseline fixture power consumption and fixture quantities for each line item in the inventory OR total circuit load.

Post-Installation M&V Activities and Energy-Use Savings Calculations

- Audit and inspect lighting installation to confirm final fixture counts
- Measure fixture power for lamp + driver/ballast combinations representing a total of 75% of the baseline connected load (i.e., a minimum of 75% of the circuit load or 75% of the individual fixtures).
- Assume that operating hours are the same as baseline operating hours for direct lamp technology comparisons assuming standard dawn to dusk on-off control. If controls have been added or modified that effect energy savings, the Operating Hours should be measured or estimated based on documented research or cases studies.
- Verify that post-installation energy use is based on product of the verified post-installation fixture power consumption, operating hours, and fixture quantities for each line item in the inventory OR product of total circuit load and operating hours.
- Verify that post-installation demand is based on product of the verified post-installation fixture power consumption, and fixture quantities for each item in inventory OR total circuit load.
- Calculate savings as the difference between the baseline and post-installation energy use and power demand.

Annual or Periodic M&V Activities:

- Inspect approximately 10% of the area or fixtures retrofitted.
- Report deficiencies that effect energy savings to facility representative.

M&V PLAN DETAILS

The standard M&V Plan assumes several conditions for the measurements to be useful for comparison of different technologies:

- Operating hours are identified during the initial energy survey, and are assumed to be the same before and after the equipment retrofit for the purpose of energy-savings calculations. Savings associated with different operating hours are not part of the energy savings methodology detailed here. In addition, energy savings associated with changes to controls between baseline and post-installation conditions are treated as a separate energy improvements and should not be included in this comparison.
- Interactive effects on heating and cooling systems from the lighting baseline and post-installation equipment are not considered for interior or exterior installations. While heating and cooling will be affected for interior installations, in most cases, the heating and cooling interactions generally cancel each other or are relatively minor.
- Electricity demand and associated charges are not considered for exterior installations. Exterior lighting rarely affects demand, and associated charges for most utilities because utility power peaks rarely occur at night.
- Lighting levels (photopic illuminance) are assumed to be appropriate for the task needs in both the baseline and post-installation conditions. If lighting levels in the baseline case are not high enough to meet task needs, the lighting should be repaired, refreshed, or modified to meet lighting needs in order to support an appropriate comparison.

1.3 Baseline and Post-Installation Selection and Setup

An effective comparison of lighting technologies must be conducted in an environment and under conditions that eliminate unnecessary variables that could invalidate the comparison results. It is understood that all installations and real-world conditions are unique; however, an equal set of conditions are needed to provide a basis for reasonable comparison. Each of the setup conditions described below should be evaluated and followed as closely as possible:

<u>Fully-Operational Baseline</u>

The baseline lighting system should be fully functioning in a manner equal to having been either recently installed or refreshed. This is needed for an accurate comparison of technologies considered for use. If possible, the system should be cleaned with a damp cloth, and refreshed with new lamps that have been seasoned for 100 hours before testing. For an optimum comparison, the light levels in the baseline condition should be set equal to the appropriate levels for the task, if possible. This should also match closely with the target light levels for the retrofit technology.

If refreshing the system lamps is not possible, it is important to complete power and light level measurements on portions of the system that are fully functioning. However, this will not necessarily provide a true comparison of two technologies because of natural degradation of the baseline lamps. In this situation, the age of the lamps used for measurement should be recorded where possible. Modeling the lighting can be used to assist in these cases where equipment status and/or degradation do not permit reasonable assessment of existing conditions.

Stable Conditions for Measurement

For an effective comparison test, the site should be chosen such that the surrounding conditions will remain the same for the time required to complete both the baseline and post-installation retrofit testing. Changes in surrounding structures, occupants, weather, or other conditions could affect the results and may make comparative measurements difficult.

Measurement Access

Accurate and repeatable measurements of power and light levels for baseline and post-installation conditions require ready access to the system power service and the illuminated area. The test site should have easy access to the circuits serving the test lighting system. The illuminated area should be available for light level measurements during periods when potential obstructions can be avoided (e.g., vehicles, occupants, customers, and temporary materials or equipment).

1.4 Baseline and Post-Installation Power Measurement

The measurement of baseline and post-installation power can be accomplished with one of two primary methods. One is measurement of the entire electrical circuiting encompassing the replacement project. The other is a sampling measurement of representative fixtures. The measurement of the power on the circuiting encompassing the project is generally the preferred option as it captures the true power consumption without any calculation or use of average values. In many cases this may also be the easiest method to implement.

Circuit Measurement Method

The circuit measurement method involves identifying the circuit(s) that serve the baseline and post-installation lighting system (they will typically be the same circuits) and measuring the power to at least 75% of the total load. This provides a direct representative measurement of actual power for the project. If all fixtures are not included in the measurement, the total load can be calculated from this representative measurement by prorating to the total quantity of fixtures. **It is important to ensure that the circuits identified and measured do not have other loads on them.** If other loads are present and constitute a small percentage of the total lighting load (less than 10%) and they can be separately measured, the circuit can still be used. In this case, also separately measure the non-lighting load at the same time as the circuit measurement and subtract to determine the lighting-only load.

Sampling Measurement Method

The sampling measurement method involves measuring the power draw of a sample of each type of fixture (existing and replacement) and calculating an average of these measurements for use as a per-fixture power rating. The total project power is then calculated as the product of the average fixture power and the fixture quantities. The sample size to be measured for each separate fixture type shall be a total of six fixtures of that type, or the entire set if less than six. It is important to note that a consistent comparison of technologies should assume normal operating conditions for both cases. Therefore, identify and measure only normally operating fixtures for the baseline (and post-installation) test.

For new equipment (replacements), power measurements should be made after at least 100 hours of operation of each fixture. Fixtures for both baseline and post-installation must also be allowed to warm up prior to measurement in order to achieve typical operating temperature. Appropriate warm-up periods are as follows:

- Fluorescent sources: 15 minutes.
- HID sources: one hour.
- LED sources: 10 minutes.

1.5 Baseline and Post-Installation Operating Hours

For direct evaluation of lamp + ballast/driver retrofits and installations, operating hours should be considered to be the same for both baseline and post-installation conditions.

If controls have been added or modified as part of the installation, the associated energy savings should be separately calculated. If the controls modification or addition incorporates timed control such as on-off schedules, the calculation can be based on measurement of the new operating hours or documenting an estimate based on timer or schedule settings.

If new controls are not time-based such as occupancy sensors or dimming controls, then capturing operating hours will not support an accurate calculation. In these cases, circuit energy use will need to be measured for representative periods of time (minimum of two weeks) to capture representative energy use, which replaces the calculation of load multiplied by operating hours.

1.6 Light Level Measurement

Light level (i.e., illumination) measurements are critical to comparing the capabilities of different lighting technologies. It is important to make measurements to capture only the light being provided by the technologies being tested, which represents the actual illumination provided by the system being measured. The following guidelines for measurement should be followed to ensure accurate and representative light level data.

For **ALL** measurements:

- o Where possible, use the same calibrated illuminance measurement meter (see Section 2.1). If the same meter is not available, use the same make and model of calibrated meter to minimize any underlying differences in accuracy and internal meter spectrum correction characteristics.

- When taking measurements, verify that occupants and objects/materials are not blocking the meter head. The use of a remote head cabled to the meter is suggested so that the operator will not block the meter's "view" of the lighting system being measured.

- Identify the appropriate task plane at which to take the measurements. For most outdoor areas and indoor corridors, gathering spaces, and warehousing or manufacturing spaces this will be the ground or floor surface (where walking is the primary task). For most other indoor areas the task plane will be a typical office desk height (30" from floor).

- Identify the measurement locations by marking and/or mapping. It is important to measure the baseline and post-installation lighting systems using the same measurement locations, or the same representative type of locations if fixtures are relocated for the retrofit.
    - For **interior** areas, mapping (e.g., using a sketch, marked up plans, etc.) is usually the best option as marking will typically not be allowed. Make sure to reference the measurement points to some permanent features of the space since desks and other furniture may be moved between the baseline and post-installation measurements.
    - For **exterior** areas such as parking lots, it may be possible to mark locations with dots or numbers using striping or other paint (durable but non-permanent), subject to site representative approval. Otherwise a map of the measurement grid referenced to permanent site features can be developed such that the same measurement locations can be identified later. It is advisable to map the measurement points even if marking is possible – in case the exterior area is resurfaced or otherwise cleaned of all markings.
- Photographs of the test site conditions, meter setup and measurement layout are recommended to provide a record of the conditions to be applied for repeated sets of measurements. These will help identify obstructions and other conditions that may affect readings.

For **EXTERIOR** area measurements:
- Identify a grid of measurement points that sufficiently represents the overall lighting of each different exterior area for both baseline and post-installation conditions: (see sample layouts in Appendix B)
    - For areas with poles spaced more than 15-feet apart, locate measurement points directly below poles and at quarter- and midpoints between poles in both directions. Ensure that measurement points are not farther apart than half the pole height.
    - For areas with poles spaced less than 15-feet apart, locate measurement points directly below poles and at least at midpoints between poles in both

directions. Ensure that measurement points are not farther apart than half the pole height.

    - For open areas such as parking, make the measurement grid large enough to completely encompass at least 4 poles (or the complete installation). Also include the area extending from the outermost poles in the measurement grid at least halfway to the next closest fixture outside the grid, or the edge of the site property.
    - For perimeter parking or drive areas, establish the measurement grid from the site boundary inward to the nearest line of lighting poles that are not within 5 feet of the boundary. The measurement grid should be at least as wide as the distance between two representative adjacent lighting poles.
    - For areas adjacent to the building façade (e.g., front drive aisle, rear drive, pallet/loading), establish the measurement grid from the façade to the nearest parking spots, outer edge of the drive, or site boundary. The measurement grid should be at least as wide as the distance between two representative adjacent lighting poles.
    - For all other areas including main entry drives, establish the measurement grid across the entire drive or other area and extending the typical distance between two adjacent lighting poles.
- At each measurement point on each grid, measure and record the horizontal illuminance on the ground or finished surface. See Appendix A for additional specific guidance on producing repeatable and accurate measurements.
- For each separate grid, select a line of points extending diagonally between two opposite corner poles in a set of four (or a configuration representative of this). At each point measure the vertical illuminance at 5 feet off the ground or finished surface perpendicular to the line of points in both directions (see Appendix A). For areas that include the site boundary, measure the vertical illuminance at the line of boundary points facing into the site. For all areas, exclude any measurements at points on the boundary facing away from the site.
- Schedule and take all measurements so as to minimize the effects of other light sources and weather conditions on the results:
    - Schedule measurements for both baseline and post-installation when the moon phase is at half or less, which will typically have minimal effect on the area lighting measurements. It is recommended that a background measurement of ambient lighting (e.g, moonlight, sky glow) be taken in an area shielded from all other lighting, and subtracted from other measurements if it is determined to be significant.
    - Ensure that rain, fog, or winds that might introduce particulates into the air, or other conditions that might obscure the light between the fixtures and the meter are not present for the measurements.
- Photographs of the test site conditions, meter setup and measurement layout are recommended to provide a record of the conditions to be applied for repeated sets of measurements. These will help identify obstructions and other conditions that may affect readings.

For **INTERIOR** area measurements:

- Identify a set of measurement points that sufficiently represents the overall lighting of the space for both baseline and post-installation conditions: (see sample layout ion Appendix B)
    - For each different set of lighting conditions (i.e., different space types or lighting layouts), locate a total of at least 12 measurement points at easily identifiable points. Select a sampling of measurement points both below and between fixtures, in both 90 degree directions and diagonally, and in as close to a uniform grid pattern as possible. See Appendix A for additional specific guidance on producing repeatable and accurate measurements.
    - For circulation-type spaces such as corridors and gathering spaces, establish a measurement grid on the task surface (floor) that includes representative points both directly beneath and between fixtures.
    - For office and other task areas, make measurements on desktops and other task work surfaces that best represent lighting conditions in the space.
- Schedule and take all measurements so as to minimize the effects of other light sources and location conditions on the results:
    - Schedule measurements for both baseline and post-installation when there is no daylight contribution to the space. This typically requires taking measurements after sunset. Adjacent electric lighting need not be blocked or turned off as long as it is noted and remains the same for both baseline and post-installation measurements.
    - Ensure that potential temporary obstructions such as occupants, temporary materials or furniture are removed for both the baseline and post-installation measurements.

1.7 Proposed Energy & Demand Savings Calculation Methodology[1]

Lighting-energy savings (kWh) are based on the difference between the baseline and post-installation power (watts), the fixture quantities, and the hours of operation. The application of additional controls will further affect the energy savings. **It is strongly recommended that lamp technology and any control savings be separately calculated where possible. This can be important in making future retrofit decisions**. For this standard M&V plan, it is assumed that the operating hours remain constant during the performance period. Simple fixture demand savings are calculated as the difference between the baseline and post-installation power (watts). For most technology comparisons, the lighting will be on during peak conditions and the hours of operation will be the same for both cases. Therefore, demand will not need to be adjusted for any coincidence with utility peak conditions.

[1] The approach described assumes a simple electric rate. If the rate uses time-of-use periods, the approach shown can be modified by calculating the energy and demand savings separately for each time-of-use period. More complex rates, such as demand ratchets, may require additional calculations.

The proposed annual lighting energy and demand savings are calculated for each set of fixtures using Equations 1 and 2 below:

$$ES = [(FP_{Base} \times N_{Base}) - (FP_{Post} \times N_{Post})] \times H \qquad \text{Equation 1}$$

$$DS = [(FP_{Base} \times N_{Base}) - (FP_{Post} \times N_{Post})] \times 12 \qquad \text{Equation 2}$$

Where:

ES	=	Annual electric energy savings (in kWh)
DS	=	Annual electric demand savings (in kWh)
FP_{Base}	=	Baseline fixture power consumption (in kW/fixture)
FP_{Post}	=	Post-installation fixture power consumptions (in kW/fixture)
N_{Base}	=	Number of baseline fixtures
N_{Post}	=	Number of post-installation fixtures.
H	=	Annual operating hours (this term may be different for baseline and post-installation if time based controls are to be evaluated as part of the energy savings)
12	=	typical number of months of demand charges in a year

Note that if the effects of non-time based controls installed in the post-installation case (occupancy sensors, dimming) are to be included in the calculation, the **calculated** energy use (i.e., $FP_{Post} \times N_{Post} \times H$) in the energy savings calculation (ES) is replaced by a representative **measured** yearly energy use for the post-installation system (see Section 3.3). Note that demand savings may also be diminished but determination of the effect requires matching monitored hourly loads with utility peak timing information.

The total annual cost savings can be determined using Equation 3:

$$ECS_{Total} = ES_{Total} \times ER + DS_{Total} \times DR \qquad \text{Equation 3}$$

Where:

ECS_{Total}	=	Total annual energy cost savings (in dollars)
ES_{Total}	=	The sum of energy savings for all sets of luminaires
ER	=	Electric energy rate (in \$/kWh)
DS_{Total}	=	The sum of energy demand savings for all sets of luminaires
DR	=	Electric demand rate (in \$/kW)

1.8 Operations and Maintenance and Other Cost Savings

O&M and other related savings are determined separately from energy savings.

1.9 Post-Installation M&V Activities

Upon completion of the retrofit installation, an as-built inventory of post-installation lighting fixtures should be supplied to ______, including the lighting drivers/ballasts and lamps actually installed, and lighting illumination levels (footcandles) in the areas specified.

Once per year, a minimum of 10% of the installation should be inspected to ensure that it is operating as installed and commissioned, and continues to have the potential to generate the expected savings. This inspection should include measurements of horizontal light levels (illuminance) at a minimum and, where practical, energy consumption. Any discrepancies in equipment function and or performance should be documented and contract arrangements reviewed to determine any appropriate contractual responsibilities.

APPENDIX A. ADDITIONAL GUIDANCE ON THE ACCURATE AND REPEATABLE MEASUREMENT OF ILLUMINANCE

Accurate and repeatable illuminance measurements can be influenced by many factors including characteristics of the measurement instrumentation, as well as the setup and execution of the actual measurements. Two major areas that require special consideration are measurements of low light levels and test site obstructions. Additional specific guidance on these two issues is provided in this Appendix.

Low Light Levels

Low light levels create particular accuracy and comparability problems for all measurements taken using standard field light measurement equipment. This is due, in part, to the typical variability among sensors and measurement electronics, which may produce different readings when measuring the same lighting source. Ambient temperatures can also affect the resulting illuminance readings by up to 1% per 10 ^{o}C ,and typically 3% over the equipment operating illuminance range. These effects can occur during any measurement but are most noticeable with low light levels where small actual differences can represent a large percentage difference.

To reduce the effects of meter accuracy and differences in sensors, the following practices should be considered:

- Use a meter with the highest overall accuracy possible which meets the specifications in Table 1 (Example Instrumentation Specifications).
- Set the meter to the lowest available measurement range if not auto-adjusted.
- Use the same meter or at least the same make and model of meter for pre and post measurements, as well as measurements between sites to ensure comparability of readings.
- Where possible, avoid extreme temperatures (towards the limits of the meter's stated operating temperature range). If extreme temperatures cannot be avoided, ensure that similar temperatures exist for pre and post measurements.

The test setup for the measurements (including handling of the meter) will also affect readings – particularly at low light levels. These measurement characteristics include:

- Location of the sensor.
- The angle of the normal (vertical vector) of the sensor with respect to the lighting being measured.
- Blockage of the sensor.
- Ambient light.

Careful test setup and measurement procedures can reduce potential variances from the handling and placement of the meter. When multiple measurements are taken and averages calculated for comparisons, minor variations in placement of the meter should have minimal effect. However, in critical areas such as perimeters and special areas where fewer measurements are taken and/or perimeter conditions are being verified, the measurement placement will be important.

To reduce the effects of test setup and meter handling, follow these guidelines:

- Ensure that critical measurement locations are marked and easily identifiable (e.g., “X’ or small dot) such that the centerpoint of the identifying mark can be accessed for each measurement.
- Ensure that the sensor head is placed parallel to the horizontal or vertical task plane (typically the paved surface or ground for horizontal exterior measurement). Many exterior surfaces are not perfectly flat, and placement of the sensor in a slightly different location can cause the sensor to tilt and produce a potentially large difference in reading. For rough surfaces, it is recommended that the sensor head be placed on a platform (e.g., a 12” x 12” square of plywood) to eliminate the effect of small surface differences on the small meter head. When using a platform, it is suggested that the sensor head be attached at the edge of the platform so that it can be more easily centered over the measurement location mark.
- For vertical measurements, a tripod is suggested to provide consistent height and angle of orientation. With particularly rough locations, a leveling bubble may be needed to ensure that the apparatus is level to the ground and that the meter head is vertical. Placing the tripod on a platform (e.g., a 3’ x 3’ square of plywood) may also help eliminate this error.
- Ensure that all measurements are made with no obstructions blocking the direct light from all surrounding luminaires. Also ensure that objects such as cars and persons are not close enough to the measurement point to reflect light onto the sensor head. For this same reason, dark clothing is recommended when taking exterior nighttime measurements.
- For exterior areas, ensure that all sources of ambient light that are not part of the typical operating conditions for the subject location do not affect the measurements. These sources could include:
    - Daylight. Delay measurements until well after sunset; even a modest amount of daylight on the horizon can effect the measurements.
    - Temporary construction lighting.
    - Vehicle lights.
    - Lighting for neighboring structures. If controlled by occupancy sensors, conduct all measurements while the lighting from neighboring structures is off. For neighboring lighting on timer controls, decide on taking measurements either with or without this lighting for all measurements.

<u>Test Site Obstructions</u>

Basic considerations for avoiding obstruction of the light to be measured are covered in the measurement section of this document (Section 3.4). However, additional issues that may not be obvious or clear are discussed here. Obstructions include objects that block the light being measured, as well as objects that reflect unwanted light. When preparing to take light measurements at a site, it is important to identify permanent obstructions that should not be adjusted or moved. However, temporary obstructions should be moved to create repeatable site configuration for light measurements. When future measurements are taken, temporary obstructions should again be moved to replicate the original site configuration.

In some cases, semi-permanent or permanent obstructions are added between sets of measurements. In these cases, the obstructions should be evaluated to determine actual effect on readings and action taken where possible. Examples are detailed here:

- Temporary piles of material, plants, and desk objects - If objects are near the test point, temporarily move them to take the measurement. To minimize these issues, test points should be located away from partitions and other nearby surfaces that might accumulate materials.
- Overhead signage and banners – Hanging interior signs and exterior pole banners are often added to locations as general improvements or for holiday events. If these will block the light for a reading, they should be removed (if possible). If not removable in a practical manner, their presence should be noted.

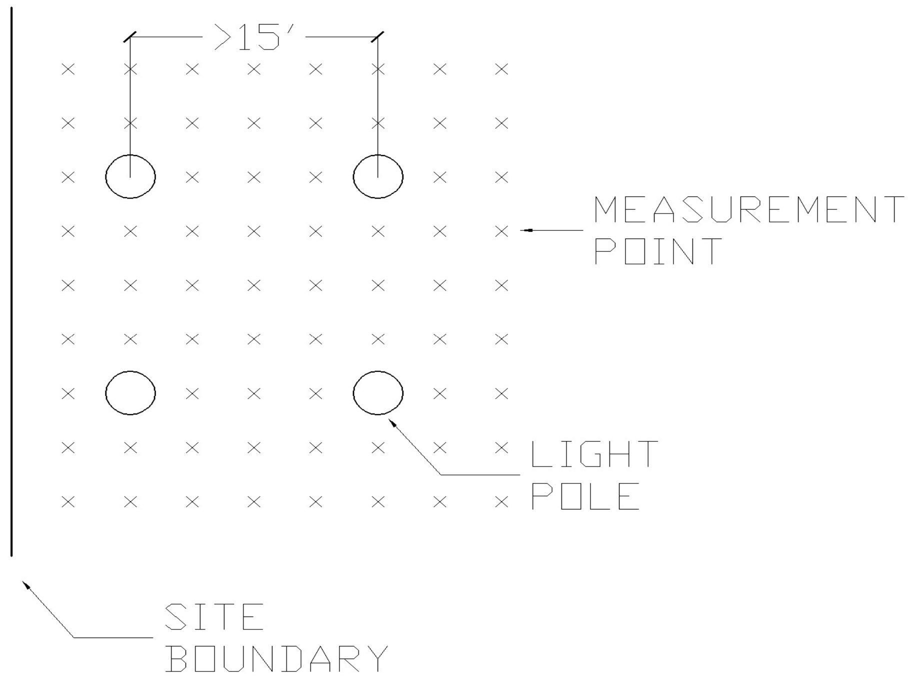
Obstructions can also cause unwanted reflection of lighting that will affect the readings required. In many cases the object reflecting the light will also be obstructing light. As described above, these objects should be moved where possible. Some temporary or newly installed objects (between sets of readings) may not be obstructing light but may reflect it into the field of view of the sensor. These might include:

- Vehicles.
- Pedestrians.
- Material stockpiles.
- Temporary furniture.
- Added wall treatments such as whiteboards.

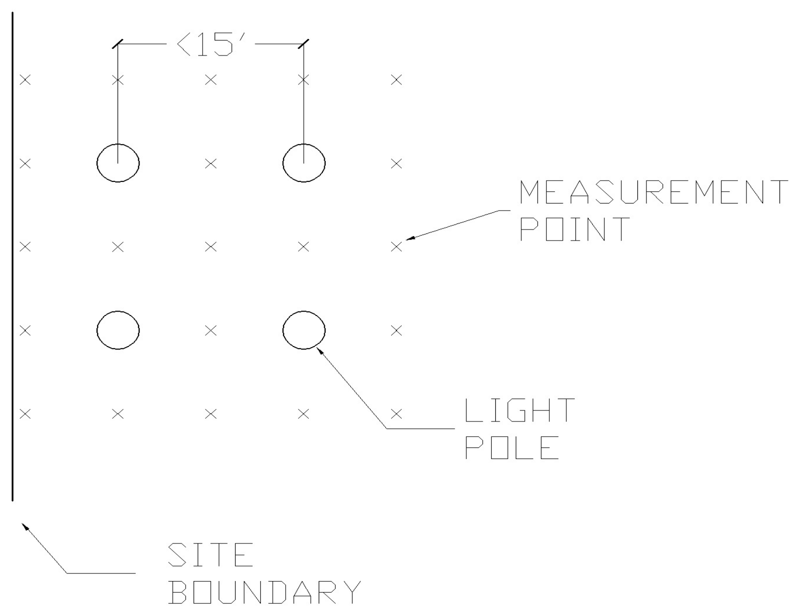
When these are encountered and are considered detrimental to light measurements, removal is the preferred option. This may be easily accomplished for vehicles, pedestrians, and furniture. However, more permanent items such as whiteboards may not be as easily removed. In these cases, their location relative to the test point should be noted. Photographs of the initial site conditions are useful as comparisons to identify changes for subsequent sets of measurements.

APPENDIX B. SAMPLE MEASUREMENT POINT LAYOUTS

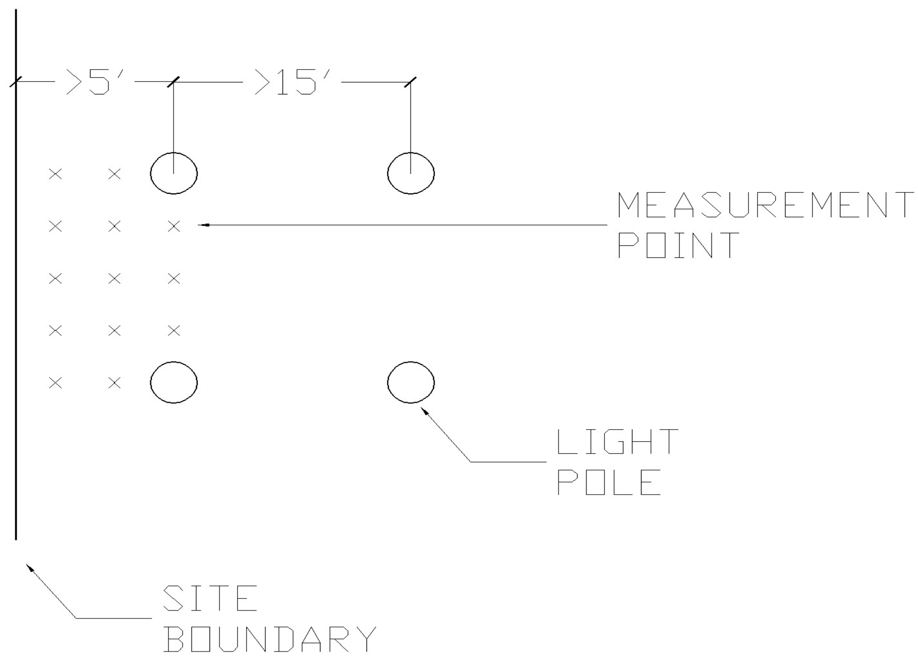
Layout 1. Open Exterior areas with poles **greater** then 15' apart



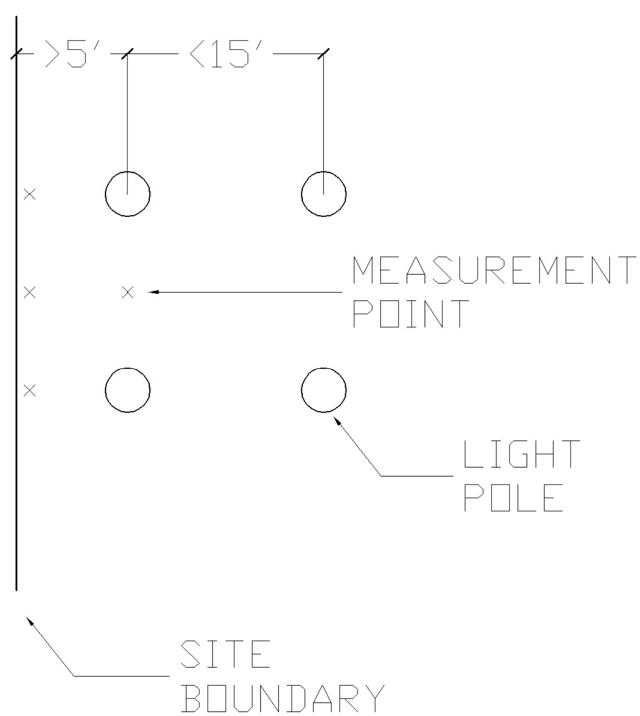
Layout 2. Open Exterior areas with poles **less** then 15' apart



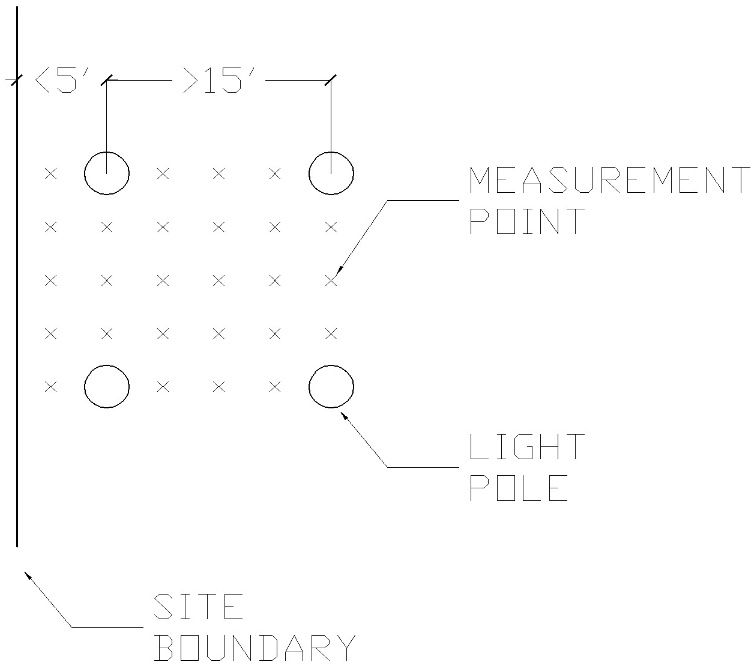
Layout 3. Perimeter and drive areas with closest poles more then 5' from site boundary and poles spaced **greater** then 15' apart



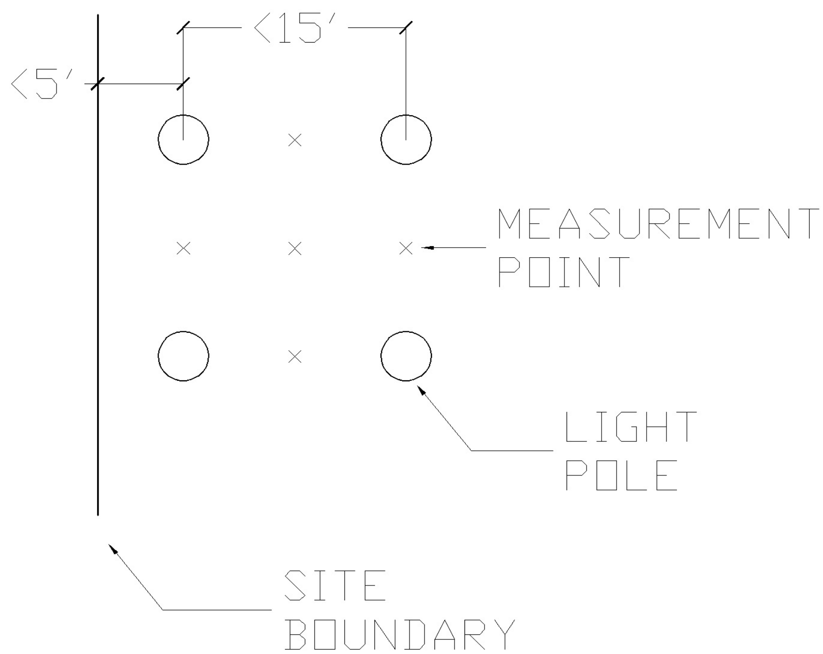
Layout 4. Perimeter and drive areas with closest poles more then 5' from site boundary and poles spaced **less** then 15' apart



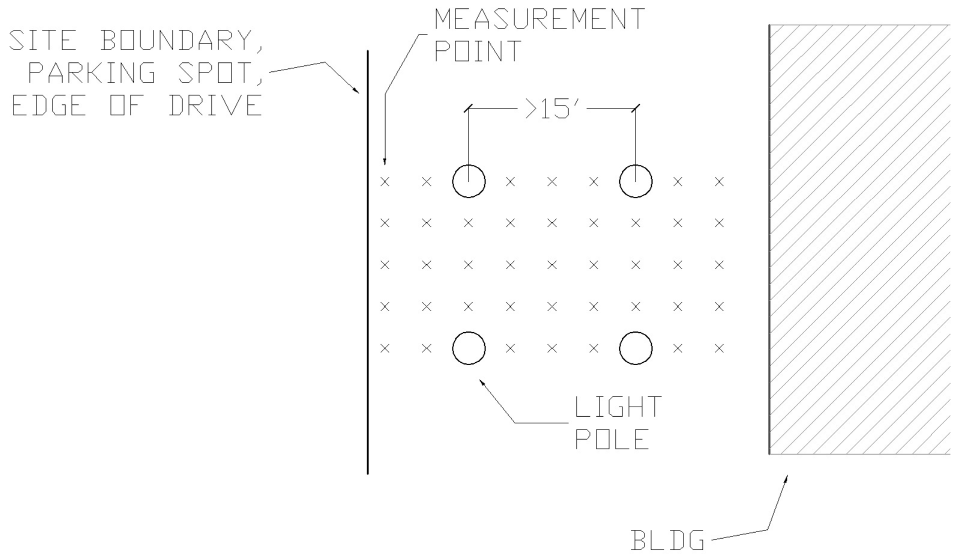
Layout 5. Perimeter and drive areas with closest poles less then 5’ from site boundary and poles spaced **greater** then 15’ apart



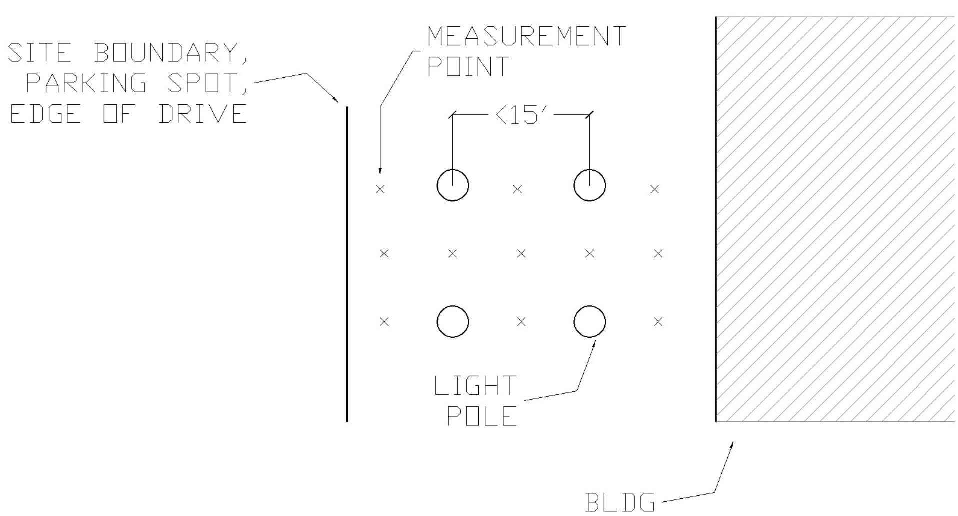
Layout 6. Perimeter and drive areas with closest poles less then 5’ from site boundary and poles spaced **less** than 15’ apart.



Layout 7. Non-parking areas between building and other boundaries such as parking spots or edge of drive with poles **greater** then 15’ apart



Layout 8. Non-parking areas between building and other boundaries such as parking spots or edge of drive with poles **less** then 15’ apart



Layout 9. Sample measurement point layout for interior measurements